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EFFECTS OF PERIODIC AND CONTINUOUS RESISTANCE TRAINING ON MUSCLE STRENGTH IN DETRAINED WOMEN[1, 2]

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Summary.—It has been reported that periodic resistance training (retraining after short-term detraining) could maintain muscle performance. However, the training volume used in previous studies differed between continuous and periodic training groups. This study compared strength gains following 20 sessions of continuous and periodic resistance training programs. 60 healthy, detrained women were randomly assigned into one of two groups: (1) continuous resistance training group or (2) retraining resistance group. The continuous resistance training group performed a non-interrupted resistance training program for 10 wk., while the retraining resistance group trained for 5 wk., detrained 2 wk., and resumed training for 5 wk. All participants performed three sets of 8–12 maximum repetitions of lower- and upper-body exercises two days per week, with at least 48 hr. between sessions. There was no significant difference on knee extensors and elbow flexors peak torque gain between the continuous resistance training group and the retraining resistance group. The results suggest that 2 wk. of detraining does not affect strength gains after a total of 10 wk. in detrained women.

It is well known that high intensity resistance training is an effective tool for improving muscle strength and size [Kraemer, Adams, Cafarelli, Dudley, Dooly, Feigenbaum, *et al*., 2002; American College of Sports Medicine (ACSM), 2009; Bottaro, Veloso, Wagner, & Gentil, 2011]. Several factors, such as training volume, intensity, frequency, and the rest interval between sets may affect the chronic response to resistance training (Kraemer, *et al*., 2002; ACSM, 2009). The improvement in muscle size and function are acquired over several weeks or months of continuous resistance training performed without periods of interruption (Kraemer, *et al*., 2002; ACSM, 2009). It has been reported that interruption or detraining periods

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may lead to a reduction or loss in strength and hypertrophy gains linked to resistance training (Connelly & Vandervoort, 1997; Taaffe & Marcus, 1997; Ivey, Tracy, Lemmer, NessAiver, Metter, Fozard, *et al*., 2000; Häkkinen, Alen, Kallinen, Newton, & Kraemer, 2000; Andersen, Andersen, Magnusson, Suetta, Madsen, Christensen, *et al*., 2005; Fatouros, Kambas, Katrabasas, Nikolaidis, Chatzinikolaou, Leontsini, *et al*., 2005; Harris, Debeliso, Adams, Irmischer, & Gibson, 2007; Taaffe, Henwood, Nalls, Walker, Lang, & Harris, 2009; Correa, Baroni, Radaelli, Lanferdini, Cunha, Reischak-Oliveira, *et al*., 2013). Detraining has been defined either as partial or complete loss of trained-induced adaptations (Hortobágyi, Houmard, Stevenson, Fraser, Johns, & Israel, 1993; Mujika & Padilla, 2001) or cessation of training (Ogasawara, Yasuda, Ishii, & Abe, 2013).

Some studies reported that strength gains could be partially maintained after three mo. (as percent of strength gain: 70% and 12%; Taaffe & Marcus, 1997; Correa, *et al*., 2013), five mo. (49%; Harris, *et al*., 2007), six mo. (73 and 46%; Häkkinen, *et al*., 2000; Taaffe, *et al*., 2009), and even eight mo. (52%; Staron, Leonardi, Karapondo, Malicky, Falkel, Hagerman, *et al*., 1991) and 12 mo. of detraining (31.5%; Fatouros, *et al*., 2005). These studies recruited untrained young women (Staron, *et al*., 1991), physically active middle-aged men and women (Häkkinen, *et al*., 2000), and untrained elderly men (Taaffe & Marcus, 1997; Fatouros, *et al*., 2005) or women (Correa, *et al*., 2013) or both (Harris, *et al*., 2007; Taaffe, *et al*., 2009). Moreover, Ivey, *et al*. (2000) observed that strength gains were also partially maintained after 8 mo. of detraining in young men (67.6%) and women (74%), as well as in older men (33.7%)—but not in older women. Additionally, Kubo, Ikebukuro, Yata, Tsunoda, and Kanehisa (2010) showed that strength gains were fully preserved after 3 mo. of isometric knee extension training following 3 mo. of detraining.

To the best of the authors' knowledge, four studies have evaluated the effects of short-term (<1 mo.) resistance detraining period on strength gains (Hortobágyi, *et al*., 1993; Häkkinen, *et al*., 2000; Ogasawara, Yasuda, Sakamaki, Ozaki, & Abe, 2011; Ogasawara, Yasuda, *et al*., 2013), and just three studies evaluated the effects of periodic training (retraining following a short-term detraining period) on muscle strength (Häkkinen, *et al*., 2000; Ogasawara, *et al*., 2011; Ogasawara, Yasuda, *et al*., 2013). Ogasawara, *et al*. (2011) verified that three weeks of detraining during a 15 wk. resistance training program (total of 36 training sessions) did not affect strength gains when compared to continuous 15 weeks of resistance training (total of 45 training sessions). In the same way, it was reported that three cycles of 6 weeks of resistance training, with 3 wk. detraining periods between training cycles, resulted in similar strength increases compared to continuous 24 weeks of training (total of 54 vs. 72 training session, respectively) (Ogasawara, Yasuda, *et al*., 2013). However, the number of training sessions used in these studies was different between continuous and periodic training groups (Ogasawara, *et al.*, 2011; Ogasawara, Yasuda, *et al.*, 2013), and another study did not use a continuous training group in the experimental design (Häkkinen, *et al.*, 2000). The non-equalized number of training sessions is an important source of bias since it is one of the most important acute variables for strength gain (Gillam, 1981; McLester, Bishop, & Guilliams, 2000; Rhea, Alvar, Burkett, & Ball, 2003; ACSM, 2009). Furthermore, in the aforementioned studies (Ogasawara, *et al.*, 2011; Ogasawara, Yasuda, *et al.*, 2013) only lower (Häkkinen, *et al.*, 2000) or upper limbs (Ogasawara, *et al.*, 2011; Ogasawara, Yasuda, *et al.*, 2013) were evaluated, whereas no study has simultaneously assessed strength gains of the lower and upper limbs after continuous and periodic resistance training using the same training volume.

It has been reported that lack of motivation and lack of time is often cited as the main cause of dropping out of training programs (Trost, Owen, Bauman, Sallis, & Brown, 2002; Surakka, Alanen, Aunola, Karppi, & Lehto, 2004). Additionally, adherence to training programs is lower in young women than in young men (van Daalen, 2005). If two weeks of detraining has no detrimental effect on strength gain, it could be used to improve adherence to resistance training. Thus, evaluation of the effect of a short-term resistance detraining period on strength gains could help strength and conditioning trainers to create better programs for strength training periodization.

Previous studies showed that retraining following short-term detraining resulted in similar muscle adaptation compared to those observed during the early phase of training, despite completing a lower training volume (Ogasawara, *et al.*, 2011; Ogasawara, Yasuda, *et al.*, 2013). Thus, the hypothesis is that periodic resistance training will cause greater strength increases compared to continuous training with the same amount of training sessions. The rationale for this hypothesis was based on adaptive response of muscle tissue to resistance training. Resistance exercise stimulates muscle anabolism, which leads to muscle hypertrophy. However, due to muscle tissue adaptation this process becomes progressively slower with time. Additionally, the sensitivity of anabolic signaling is restored after a short detraining period, while it becomes reduced with chronic resistance training (Ogasawara, Kobayashi, Tsutaki, Lee, Abe, Fujita, *et al.*, 2013). Therefore, the aim of this study was to compare the strength gains following 20 sessions of non-interrupted and periodic resistance training in detrained young women.

Method

Participants

Sixty young Brazilian women volunteered for the study. The participants were recruited through folders and advertising banners around the University of Brasilia campus. To be accepted, participants had to be at least 18 years of age, not been participating in any resistance-training program over the past 6 mo., and be free of health problems that could be aggravated by the experimental procedures. To be included in the analysis, the participants had to attend at least 80% of the training sessions (Gentil & Bottaro, 2013). All participants were instructed to not change their nutritional habits; if any relevant change was detected (e.g., becoming a vegetarian, being on caloric restriction, use of nutritional supplements or ergogenic substances, etc.), the data of the participants were not included in the analysis. Data of 13 participants were not included for failing to meet the inclusion criteria: (a) regular practice of resistance training during the previous 6 mo. ($n=6$), (b) low attendance ($n=4$), and (c) performance of additional resistance training ($n=3$). All participants were notified about the experimental procedures, benefits, and risks before signing the informed consent form. An institutional research ethics committee granted approval for the study.

Measures

A Biodex System 3 isokinetic dynamometer (Biodex Medical, Inc., Shirley, NY) was used to assess unilateral elbow flexion and knee extension peak torque. In order to measure elbow flexion isokinetic peak torque, the participants sat upright with the right arm comfortably supported with a soft cushioning pad on a Scott Bench (i.e., Preacher Curl). The lateral epicondyle of the right humerus was aligned to the axis rotation of the dynamometer's lever arm. A supinated position of the forearm was maintained throughout the test. During peak torque assessment of the right knee extension, the participants sat upright with the lateral femoral condyle of the right knee aligned with the axis rotation of the dynamometer arm, allowing free and comfortable knee flexion and extension from 80° flexion to full extension (0°). Extra body movement was prevented by using belts fastened across the thigh, pelvis, and trunk. Moreover, the dynamometer was calibrated according to specifications contained in the instruction manual.

For both the elbow flexion and knee extension isokinetic test, the participants performed two sets of four repetitions at 60° sec.^{-1}, with 60 sec. rest between sets (Gentil & Bottaro, 2010). The highest peak torque achieved throughout all repetitions was recorded. Gravity correction was obtained by measuring the flexor torque produced by the dynamometer's lever arm and the participant's relaxed segment at full extension. The participants were familiarized with the dynamometer 48 hr. before testing. They were also instructed not to intake medications, caffeine, or supplements during the study period. The same examiner administered all testing procedures, and all individuals received verbal encouragement throughout the test (Brown, 2000). Baseline test and retest intra-class correlation coefficient

(ICC) and the standard error of the measurement for peak torque were 0.98 and 7 Nm for knee extensors, and 0.96 and 1.80 Nm for elbow flexors, respectively.

Study Design and Procedure

Sixty college-aged young women were randomly divided, using a random number table, into two groups: (1) continuous resistance training group and (2) resistance retraining group. Both groups performed the same resistance exercise training program in a total of 20 training sessions divided into two nonconsecutive training days per week. The continuous resistance-training group trained continuously during 10 weeks, while the resistance retraining group trained for 5 weeks, stopped for a period of 2 weeks, and then resumed training for 5 more weeks. Strength assessments in the knee extension and elbow flexors were taken on an isokinetic dynamometer before and after the training period. Differences in knee extensors and elbow flexors strength gains in response to different resistance training regimens were compared between the continuous resistance training and resistance retraining groups.

Regarding resistance training protocol, all participants of both the continuous resistance training and resistance retraining groups performed the same compound exercises, following the same order (leg press, knee flexion, lat pulldown, and bench press). Single-joint exercises (i.e., biceps curl and knee extension) were not included in the resistance exercise training program (Gentil, Soares, Pereira, Cunha, Martorelli, Martorelli, & Bottaro, 2013). Therefore, the only difference was the training continuity. All exercises were performed with three sets of 8–12 repetitions maximum. If necessary, loads were adjusted at each set to maintain the designed number of repetitions (Gentil, *et al.*, 2013). The participants were instructed to perform exercises with a cadence of 2 sec. for the concentric phase and 2 sec. for the eccentric phase, without pausing between phases. During the training sessions, music tracks with 120 bpm were played to facilitate control of movement speed. The participants were oriented to perform all sets until concentric failure. If necessary, loads were adjusted from set to set to maintain the designated number of repetitions. Training sessions were closely supervised by a certified exercise technologist. Previous research has demonstrated greater gains in supervised vs. unsupervised training (Gentil & Bottaro, 2010). Training was conducted two days per week, with a minimum of 48 hr. between sessions. The rest interval between sets ranged from 1.5 to 2.5 min. Moreover, there were 2 weeks of familiarization before the training period. During familiarization sessions, the participants were instructed how to correctly perform the exercises and the initial loads were obtained.

Statistical Analysis

Physical characteristics, elbow flexors, and knee extensors peak torque are presented as means and standard deviations. The Kolmogorov-Smirnov test was used to check physical characteristics and peak torque data for normal distribution. Considering that the data were normally distributed, a 2 × 2 [group (continuous resistance training and resistance retraining groups) × time (pre- and post-training)] repeated-measures analysis of variance (ANOVA) was used to analyze peak torque. In the case of significant differences, a Tukey's *post hoc* test was used. The physical characteristics and baseline peak torque values were evaluated by using an independent *t* test. Significance level was set *a priori* at $p < .05$. The analyses were performed using SPSS (Version 17.0). For effect sizes, Cohen's *d* values of 0.2, 0.5, and 0.8 were used to define small, medium, and large *d* values, respectively, obtained from differences between pre- and post-training scores divided by the pooled standard deviation (Beck, 2013).

Results

Age, body mass, height, and elbow flexors and knee extensors baseline peak torque were not significantly different between groups (Table 1). Figures 1 and 2 show elbow flexors and knee extensors peak torque, respectively, before and after 10 weeks of resistance training in both groups. There was no significant interaction or main effect of group for either elbow flexor or knee extensor peak torque. However, there were main effects for time for both elbow flexor ($p < .001$) and knee extensor ($p < .001$) peak torque. The effect size for elbow flexors strength gains in the continuous resistance training ($d = 0.63$) and resistance retraining ($d = 0.58$) groups were medium. Additionally, the effect size for knee extensor strength gains for both continuous resistance training ($d = 0.55$) and resistance retraining ($d = 0.63$) groups were medium.

TABLE 1

Physical Characteristics, Elbow Flexors, and Knee Extensors Baseline Peak Torque of Each Experimental Group

	CTR Group ($n = 24$)		RTR Group ($n = 23$)		p
	M	*SD*	*M*	*SD*	
Age, yr.	21	2	21	3	.67
Body mass, kg	58.65	8.1	57.6	10.58	.07
Height, cm	161.8	6.5	167.2	8.2	.69
Elbow flexors peak torque, Nm	25.6	4.4	24.5	5.3	.44
Knee extensors peak torque, Nm	144.1	26.9	131.8	26.0	.12

Note.—CTR: Continuous resistance training group; RTR: Resistance retraining group.

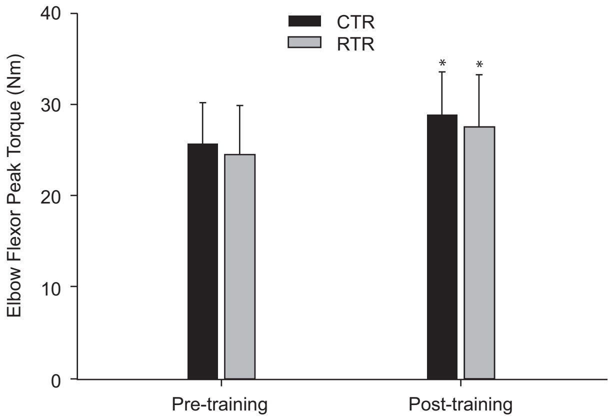

FIG. 1. Elbow flexor peak torque pre- and post-training in Continuous resistance training (CTR) and Resistance retraining (RTR) groups. $^*p < .05$, greater than pre-training.

DISCUSSION

The study compared the effect of prolonged resistance training, detraining, and re-strength training on muscle strength gains using the same number of training sessions. The initial hypothesis was not confirmed because retraining following a 2 wk. period of detraining resulted in similar strength gains compared to the group that trained continuously. A 2 wk. period of detraining was used in this study because the majority of the population that train continuously can suffer interruptions due to lack of motivation, lack of time, and exercise-induced injuries (Trost, *et al.*, 2002; Surakka, *et al.*, 2004).

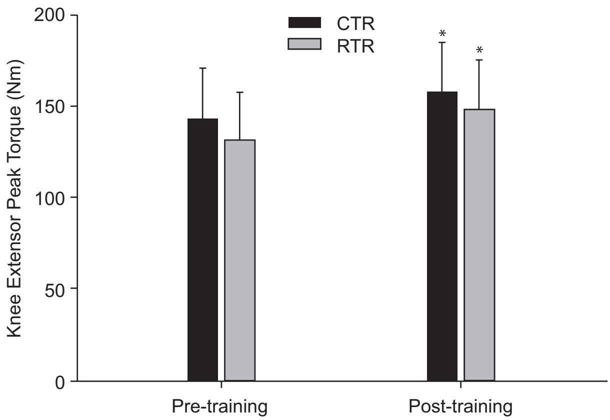

FIG. 2. Knee extensor peak torque pre- and post-training in Continuous resistance training (CTR) and Resistance retraining (RTR) groups. $^*p < .05$, greater than pre-training.

Considering that even recreational weightlifters have difficulties performing training programs continuously (Hass, Garzarella, De Hoyos, & Pollock, 2000), the knowledge that a periodic resistance training program results in similar strength gains as continuous resistance training may lead to greater adherence in resistance training programs. This hypothesis is based on common thought that training adaptations do not occur or are impaired if the training program is stopped periodically. On the other hand, the similar strength gains between periodic resistance training and continuous resistance training programs may permit that those subjects who are afraid to stop the training program can stop it periodically for 2 weeks.

The results of the present study corroborated the findings reported by Häkkinen, *et al*. (2000). These authors did not observe changes in knee extensors' one-repetition maximum (1-RM) strength after a 3 wk. detraining following a 24 wk. resistance-training program in middle-aged men. In addition, there were increases of 5% in 1-RM strength of the knee extensors during a 21 wk. retraining period. Moreover, knee extensors' isometric peak torque decreased 6% after detraining, but it returned to pre-detraining values during the 21 wk. retraining. However, this study did not evaluate a continuous resistance-training group. In addition, the study showed that periodic training consisting of 6 weeks of training, with 3 weeks of detraining followed by a 6 wk. retraining period, caused similar increases in 1-RM bench press and elbow extensors isometric strength compared to 15 wk. continuous resistance training (Ogasawara, *et al*., 2011).

Ogasawara, Yasuda, *et al*. (2013) also found similar 1-RM bench press and isometric elbow extensors strength gains after three cycles of 6 wk. resistance training, with 3 wk. detraining periods between training cycles compared to continuous 24 wk. training. Nevertheless, the continuous and periodic training groups did not perform the same number of training sessions in these studies (Ogasawara, *et al*., 2011; Ogasawara, Yasuda, *et al*., 2013). To the best of the authors' knowledge, the present study was the first to evaluate lower and upper body strength after continuous and periodic resistance training with the same number of training sessions and equated volume between them. It is important to highlight this issue because the number of training sessions could be an important source of bias on training-induced adaptations. It has been reported that a greater number of training sessions within a training period leads to a greater strength gain in untrained participants (Gillam, 1981; McLester, *et al*., 2000; Rhea, *et al*., 2003).

It is clear that muscle strength gains are produced following several weeks or even months of continuous resistance training (Kraemer, *et al*., 2002; ACSM, 2009). However, the rate of muscle adaptation is not linear following long-term resistance training. The greatest gains have been observed in the early phase (i.e., 10 wk.) than the later phase (Ikai & Fukunaga, 1970;

Sale, 1988; Abe, DeHoyos, Pollock, & Garzarella, 2000; Wernbom, Augustsson, & Thomee, 2007). In this way, it has been suggested that periodic training with short-term detraining followed by a retraining period is also an effective tool for improving muscle size and function compared to continuous training (Ogasawara, *et al*., 2011; Ogasawara, Yasuda, *et al*., 2013). In addition to producing similar benefits as continuous training, the retraining phase of periodic training may lead to muscle adaptation comparable to that observed during the early phase of training (Ogasawara, *et al*., 2011; Ogasawara, Yasuda, *et al*., 2013). This assumption is supported by Ogasawara, Kobayashi, *et al*. (2013) who verified that anabolic signaling in animals becomes less sensitive with chronic resistance training; however, it was restored after a short detraining period. This process may be linked to skeletal muscle ability to adapt to resistance exercise, then reducing the cellular disturbances caused by subsequent stimulus. Moreover, triceps brachii hypertrophy gains and 1-RM bench press strength gains were similar between the initial 6 wk. continuous training period and during the first and second 6 wk. retraining periods (Ogasawara, Yasuda, *et al*., 2013). On the other hand, the rate of increase in these variables was gradually reduced throughout the continuous resistance training program (Ogasawara, Yasuda, *et al*., 2013). Ogasawara, *et al*. (2011) also showed a similar rate of gain in the triceps brachii cross-sectional area and 1-RM bench press strength between the retraining period and initial phases of training. However, further studies on this are necessary to confirm this hypothesis, since Mitchell, Churchward-Venne, Parise, Bellamy, Baker, Smith *et al*. (2014) showed that anabolic signaling over 6 hr. following the training session did not correlate with muscle hypertrophy over 16 wk. of resistance training in humans.

It is known that decreases in muscle strength are related to the duration of the detraining period (Staron, *et al*., 1991; Connelly & Vandervoort, 1997; Taaffe & Marcus, 1997; Häkkinen, *et al*., 2000; Ivey, *et al*., 2000; Andersen, *et al*., 2005; Fatouros, *et al*., 2005; Harris, *et al*., 2007; Taaffe, *et al*., 2009; Correa, *et al*., 2013). Regarding short-term detraining, some studies reported that 1-RM and isometric strength remained constant after 2 (Hortobágyi, *et al*., 1993) and 3 weeks of detraining (Häkkinen, *et al*., 2000) in young and middle aged participants. Electromyography activity appears to not decrease after a 3 wk. detraining period (Häkkinen, *et al*., 2000). Similarly, cross-sectional muscle area was not altered after three (Ogasawara, *et al*., 2011) and 4 weeks of detraining (Hather, Tesch, Buchanan, & Dudley, 1991). On the other hand, slight decreases in 1-RM strength (−2.0 and −3.3 %) and cross-sectional area (−2.6 and 2.9%) have been reported after the first and second 3 wk. detraining periods, respectively (Ogasawara, Yasuda, *et al*., 2013). Considering that periodic training resulted in the maintenance of hypertrophy (Hather, *et al*., 1991) and electromyography activity (Hortobágyi, *et al*., 1993; Häkkinen, *et al*., 2000), one could suggest that similar strength increases between both groups of the current study could be due to preservation of hypertrophy and neural adaptations after a short-term detraining period. However, because the present study did not assess neural adaptations and muscle hypertrophy, this hypothesis remains speculative and needs to be further investigated.

In conclusion, 2 weeks of detraining does not affect strength gains after a total of 10 weeks of resistance training in previously detrained women. It is generally argued that frequency and continuity are important factors in designing resistance training. Nevertheless, the present results showed that 2 weeks of detraining was not sufficient to affect upper and lower body strength gains between the continuous and periodic resistance training programs. However, further studies on this topic are necessary to provide grounds for a more precise conclusion and understanding of periodic resistance training. It is important to highlight that the present study evaluated 2 weeks of detraining in women only. Another limitation is that the strength test was not performed immediately before and after the detraining period. In addition, it is important to assess the effect of retraining on muscle adaptation after a longer detraining period (>1 mo.) to see how long this potential "window of adaptation" can be maintained before detraining sets in. In addition, the effects of short-term detraining in other populations, such as athletes, young men, and the elderly should also be assessed.

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